Renewable and Sustainable Energy Reviews 16 (2012) 4105–4115

Contents lists available at SciVerse ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Discursive shifts in energy from biomass: A 30 year European overview

Arjan F. Kirkels*

School of Innovation Sciences, Eindhoven University of Technology, P.O. Box 513, 5600 MB Eindhoven, The Netherlands

ARTICLE INFO

Article history:
Received 23 February 2012
Accepted 10 March 2012
Available online 27 April 2012

Keywords:
Energy
Biomass
Europe
Discourse analysis
RD&D

ABSTRACT

This study aims to provide a long term overview of developments in energy from biomass in Western Europe by analyzing the discourse in RD&D and related policy. To this end, the discourse in Western Europe between 1980 and 2010 has been studied by the literature study of open literature and articles of the European Biomass Conference. In addition, a quantitative content analysis of titles of the conference has been performed. This shows the dynamics with respect to considered feedstock, conversion technology, application as well as supporting arguments for this – a dynamics that will not show in a technology or country oriented study. We distinguish four different discourses based on differentiation to scale and knowledge intensity – but that also relates to feedstock and conversion technology. This way, the complex developments can be structured and understood as shift between and within discourses. This is especially relevant as each discourse involves a different policy arena and different actors. With a still growing interest in energy from biomass, the multiple discourses seem to keep co-existing. Emphasis continues to be given to large scale and knowledge intensive processes, which will further increase the importance of the supra-national level for future developments.

Contents

1. Introduction

Over the past decades energy from biomass has been on the forefront of promises and developments in renewable energy. Its large potential and flexibility regarding feedstock, conversion technologies and end-products certainly contributed to that. As such, it has been widely reported upon. But, surprisingly, this strand of the literature has been mainly focusing on either specific technologies or national developments (e.g. [1,2]). One might argue that this reflects the strong role of national policies and developments that have proven to be of major importance [3]. However, this neglects the international effort, e.g. the EU efforts on biomass Integrated Gasification Combined Cycles in the 1990s, and more recently the EU directive on biofuels.

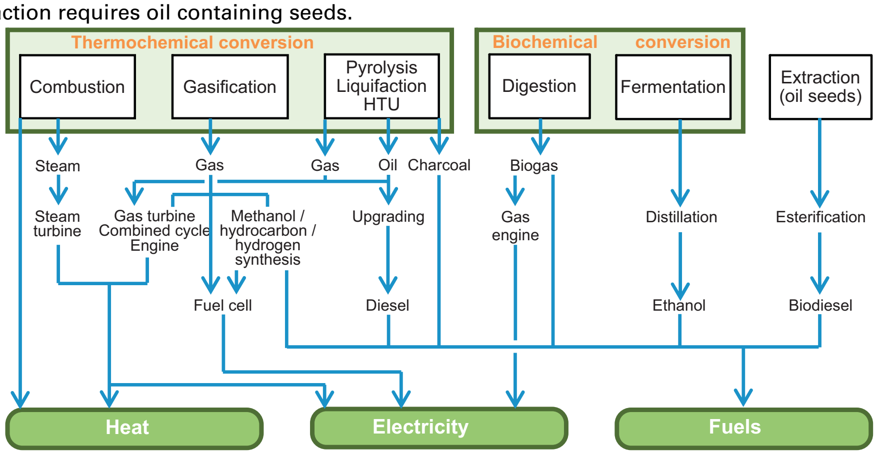
This focus is especially surprising as the general promises on energy from biomass are truly international ones: fuels from biomass as response to the international oil crises of the 1970s; energy from biomass to reduce greenhouse gas emissions since the 1990s; and more recently the promise of a bio-based economy. To life up to each of these promises requires international and large

* Tel.: +31 40 247 5761.
E-mail address: A.F.Kirkels@tue.nl

1364-0321/$ – see front matter © 2012 Elsevier Ltd. All rights reserved.
doi:10.1016/j.rser.2012.03.037

Box 1

Conversion routes energy from biomass (taken from [133]) Thermochemical routes operate under high temperature (and pressure) and often prefer dry lingo-cellulosic feedstock (wood, straw, etc.). Biochemical conversion processes are depending on the use of enzymes and bacteria that require modest temperatures and wet conditions. In general, manure and agricultural crops are the preferred feedstock. Extraction requires oil containing seeds.



scale application, as the burden of oil dependency is not levitated by a small local project, and the same hold with respect to reducing greenhouse gasses. The involved technologies ultimately serve a global market.

Our argument is not that local or national developments are not relevant; our argument is that the supranational level does matter. Our focus is on Western Europe, a region in which there has been a broad and intensive continuous RD&D effort on energy from biomass over a long period. This focus is given in by practical reasons: availability of the literature and the need to reconstruct a comprehensive story line. However, we are aware of the importance of other regions: the USA and Canada that played a leading role in the 1970s and early 80s (see, e.g. [4–6]); and more recently the developments in the USA and Asia and more specific China (e.g. [7,8]).

Although limited, several scholars did take on the international perspective on developments in Western Europe (see, e.g. [3,9,10,11]). Hall [9] is an editorial that describes to upcoming of interest in Europe in energy from biomass. His later papers [10,11] both describe the status at that time and ongoing developments in order to assess future potential of energy from biomass in Western Europe. In his well known paper, Faaij [3] follows a somewhat similar approach covering the 1995–2005 period.

We will take a somewhat different perspective, by performing a discourse analysis over a longer time horizon, 1980–2010. Our main interests and contributions are (a) how attention for specific promises and practices have developed over time and (b) the structure of the debate. As such it shows how the scenery in the energy from biomass community shifts with respect to applications and socio-economic and political context, but also with respect to feedstock and conversion technologies considered – see Box 1 . This can lead to deepening of the understanding of the ongoing developments, which is of support for policy in this field. 1980 is chosen as starting point, as it is still well covered by the literature and reflects the period in which the concerns on oil supply resulted in a renewed interest in energy from biomass that has been continued ever since.

After discussing the followed methodology, we will introduce the European Biomass Conference, the main source that we will be relying on. After that we will represent the discourses as reconstructed by two different approaches. Finally we will discuss the results and draw conclusions.

2. Methodology

2.1. Discourse analysis

Discourse analysis finds wide application in the social sciences. Object of analysis is the discussion and the argumentative structure of the discussion. This is based on the ideas of Foucault. By discourse Foucault meant "*a group of statements which provide a language for talking about – a way of representing the knowledge about – a particular topic at a particular historical moment*" [12, p. 72]. This implies a degree of repetition, in the sense that the discourse – or discourses for that matter – are shared by groups of people and show some stability over time. Several scholars emphasize that it is not a pure 'linguistic' concept, but that it is about 'language and practice', what you say and do, 'identifiable set of practices' [12,13]. But as Fairclough [14, p. 124] arguments, "*discourses not only represent the world as it is (or rather is seen to be), they are also projective, imaginaries, representing possible worlds which are different from the actual world, and tied in to projects to change the world in particular directions*". This only adds to the importance of understanding the discourse.

Discourse analysis in the field of energy from biomass seems to have drawn significant attention recently: Zschach et al. [15] have been studying the mass media discourses in leading German newspapers; Sengers et al. [16] followed a similar strategy, but focused on the biofuels debate in the Netherlands; Lehrer [17] also studied biofuels, but she focused on the US and takes a policy perspective; Huttunen [18] studied the discourses in rural non-wood bioenergy production in Finland; and finally Asveld et al. [19] focused on the debate on a bio-economy in the Netherlands. Two underlying characteristics that fueled this attention seem to be that bioenergy production has recently been widely debated worldwide and that the issue is '*multilayered and characterized by a great variety of competing interests, opinions and perceptions*', as [15] phrases it.

Most of the discourse analysis above focus on the structure of the public or policy debate and as such involve the identification of actors and advocacy coalitions involved and their position in the debate. We will take a route less travelled by, studying the discourse in the RD&D community and its involved policy. This way we hope to highlight shifts in arguments and policy and how they relate to preferences for specific feedstock, conversion technology and application – a mix of policy and technology discourse. As such, the

actors will remain more or less invisible – although one can image that a focus on agriculture crops relates to farmers; wood relates to forestry and pulp and paper industry; a focus on thermochemical conversion will require process technology, for example by boiler manufactures; a new, innovative, high-tech application will require support by RD&D institutions, etc.

2.2. Empirical approach

To reconstruct the European discourse on energy from biomass is not a straightforward thing to do. For starters, there is a lack of overview articles, as was already discussed. Also the academic literature on energy from biomass is limited prior to 1991 – at least as covered by Web of Science [20]. This does not mean that there was limited activity on this field: proceedings of conferences and policy meetings suggest the opposite. Some of the more prominent were the international Bioenergy conference of 1980 and 1984; the IEA conferences on thermochemical biomass conversion; the VTT conferences on power production from biomass in the 1990s; and last but not least the European Biomass Conference.

The European Biomass Conference is a large international conference mainly supported by the European Commission. It has been held since 1980, mostly annually or bi-annually, see Refs. [41,52,57,63,68,81,99,101,102,123–130,132]. It encompasses the whole field of energy from biomass, from biomass production and harvesting, to processing and conversion, to final application, market formation, environmental impacts and policy. From early on, it did not only include research and policy contributions, but tried to involve industry as well.

The European Biomass Conference seems to be a good starting point for reconstructing the discourse. First, the conference covers the complete period. Second, it contains a significant number of overview papers, both with respect to technology development and with respect to EU policy. And third, due to its open character and large scale, it can be seen as one of the larger European platforms for people working in RD&D on energy from biomass or policy areas related to that and as such as a representation of the energy from biomass community.

For reconstructing the discourse, we followed a two path approach. First of all, we studied conference introductions, summaries, positioning papers and overview papers over the period 1980–2010 in order to reconstruct a storyline. This storyline represents the trends as seen by leading experts and by European policy makers. For cross examination and to reduce single source bias, we also studied some of the overview papers as presented on other conferences, as well as open literature and data sources – for example with respect to the production of energy from biomass and RD&D budgets. This led to refinement and better contextualization, and as such has been included in the storyline of the first approach.

Second, we followed a quantitative approach by doing a text analysis on all contributions to the conference. The text analysis was performed using the T-lab software (see [21,22]). T-lab is a linguistic and statistical tool for text analysis. Strictly speaking, this sort of software tools support content analysis. However, we studied developments over time that we contextualized. Many scholars (e.g. [23,24]) believe that both methodologies – content analysis and discourse analysis – overlap and can be combined, as also Sengers et al. [16] have shown in their recent paper on the media discourse of biofuels.

The quantitative text analysis covers over 7000 titles. As such it is a very powerful tool and an indication of the discourse of the energy-from-biomass community as present at the conferences. For the analysis we differentiated to five periods, each more or less in line with typical time periods as distinguished by the first approach. This way it became easier to analyze developments. And as each period covers 3–4 conferences, it reduces the overrepresentation of the organizing country – that would bias a year-to-year comparison.

We used specificity analysis to compare the occurrence of key words per restricted time period (about 5 years) to the occurrence over the whole period (30 years). This provided a profile of over-used and under-used words over different periods. Only key words are included for which the probability that the frequency distribution can be explained by the distribution in the complete set is smaller than 5%.

We used T-lab under standard settings. In this modus T-lab makes an automatic selection of lemmas (key words) to be included in the analysis, excluding stop words. The output table needed further interpretation, as it was quite long: 109–151 lemmas of over used words and a bit less for under used words. It also still contained general and not very relevant terms, like *process*, *production*, *conversion*, *unit*, *move*, etc. We made a selection of most relevant lemmas (indicative of developments, meaningful) and categorized them.

Over the years the total number of contributions to the conference tripled. As a consequence, one would expect a wider variety of topics and terminology, resulting in longer lists of over-used words. However, the opposite was true: the number of over-used words decreased over time (respectively 151-188-120-109-151 words). Apparently over time some alignment of research topics and terminology has been taken place.

The interpretation required some extra care: lemmas that were completely not used in a period are not represented, nor are lemmas that are dominant over the 30 years but do not stand out in a specific period. Also, results show the time dependency of use of synonyms. In the 80s ethanol was produced, after 2000 bioethanol. This was part of a much broader tendency in naming everything 'bio', including words like biodiesel, biofuels, bioenergy, etc. T-lab does allow correcting for that, by building a dictionary in which synonyms are labeled with the same lemma. But this takes a significant effort and presents new dilemmas: bioethanol and ethanol can be considered synonyms, but should we also cluster it thematically with fermentation; and CFB, referring to circulating fluidized beds, might sometimes be synonym for fluidized bed, while in other cases it is a distinctive subset. Therefore we used the software under standard settings without defining a dictionary, checking on relevant terms using additional test where required. This approach is justified as it is used to cross-examine the literature-based-reconstruction of the discourse and any anomalies will stand out and can be checked upon.

To come to the storyline of the discourse, we used the lemmas identified by T-lab and checked upon their use in titles. This provided details of the context they were used in. In addition, we checked some lemmas on co-occurrence – for example to check to what lemmas 'market' was related to over the period 2007–2010.

3. European Biomass Conference

We already introduced shortly the European Biomass Conference, as a large international conference covering the whole field of energy from biomass. The conferences have been held annually or bi-annually, mainly by the support of the European Commission and the organizing countries (Refs. [41,52,57,63,68,81,99,101,102,123–130,132]). The general focus has been on the European scene. Both the 2000 conference in Sevilla and the 2004 conference were named 'World conference'. However, the number of international contributions did not differ from later conferences. In addition, both conferences were held in and were dominated by Europe. As such, we will treat them just like the other EU conferences – as also the organization did: the proceedings of

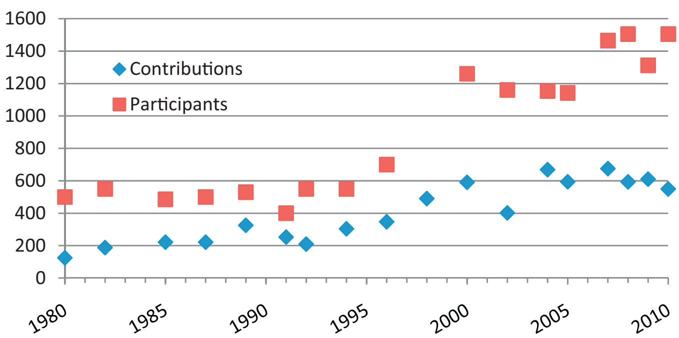


Fig. 1. European biomass conference, number of contributions and participants.

both World conferences were styled the same as the EU conferences, and in the numbering of subsequent EU conferences both World conferences are included.

Remains the question which Europe is represented by the conference, as over the considered period the EU has been gradually expanding with mainly Scandinavian and Eastern European countries. And more importantly, are the dominant countries in energy from biomass represented well over time?

First dominant European countries in the field were identified, both with respect to resource potential and application of bio-energy. Especially France and Germany have both large wood resources and agricultural output. Sweden and Finland also have large wood resources, while the latter also has large domestic peat resources. Exactly these four countries also excel in the use of energy from biomass [25–29].

Next we checked for the contributions to the conference. In the 1980s France is dominating. From the smaller countries Belgium has a relatively high share. Contributions show a strong focus on EC. For the period 1989–1996 no detailed data are available. From 1998 onwards, Italy and Germany have been the main contributing countries. The importance of smaller countries increases, especially for 1998–2002: Sweden, the Netherlands, Austria and Denmark. In general, EU contributions continue to dominate. Since the 1990s there are some contributions by Eastern European countries, but at a limited scale.

Overall, one can state that the conference does represent well EU and especially West European developments. Major misrepresentation is the lack of contributions by Sweden and Finland in the 80s. These countries excel both in resources and application of bio-energy and both countries held large relevant RD&D programs in this period, focused on combustion, gasification and liquefaction of wood, peat and black liquor [30–35].

A first characterization of the success of the conference over the years is given in Fig. 1. Both contributions and participants showed a strong increase during the late 1990s. This was due to a change in focus of the conference, enlarging the circle of participants [36], as well as a growth of interest in energy from biomass, especially over the 1994–2000 period, as we will see.

4. Literature study based discourse

The early years, **1980–1985**, are characterized by major concerns regarding high oil prices and attempts to decrease dependency on oil. Policy focuses on improving energy efficiency and alternative fuels, especially coal and nuclear (and later also natural gas) for power production. It is a period of increasing awareness on energy from biomass, in which a diversity of resources and conversion technologies is being explored – with highest priority for production of a liquid fuel for the gasoline market and displacing oil for heating purposes in rural areas. Given this diversity, neither the overall impact biomass can make nor its strategic importance is widely recognized. And although there is a need for short term application, there is also the recognition that developing the energy from biomass option will probably take a long time [37–40,42,43].

Biomass per unit land turns out to be a sensitive cost factor and considerable effort is given to improve plant productivity. Combustion, digestion and fermentation are widely used technologies. Special attention is given to demonstration of farm scale biogas production by digesters – although at the end of the '80s hopes are dashed. Combustion also receives significant attention, mainly the combustion of agricultural wastes (straw), industrial waste and RDF. Gasifiers are much less applied and mature. However, significant research focuses on production of transportation fuels, and methanol synthesis via gasification of wood is given main priority. Ethanol is initially not considered as a promising liquid fuel based on energy balance economics and competition for land. During the '80s it finds new interest, for example as co-solvent in biofuel blends, and by cellulolysis for the breakdown of lignocellulose to cellulose and subsequent fermentation, which becomes an area of very active R&D [44–49]. Lignocellulosic biomass (wood, straw, etc.) are considered most versatile, as world production is large, competition with food is limited and they can be stored and allow for steady state feeding [38,42,43].

In the subsequent period, **1985–1987**, oil prices stabilize at lower prices and no longer provide the sense of urgency that characterized the early 80s. The context shifts: on the one hand to dealing with waste and residues – a low cost feedstock that is topic of increasing environmental concern; and on the other hand to dealing with agricultural surpluses in the EU, with energy crops giving a possibility to use set aside land and provide additional income, and as such support rural areas and communities. This results in an increase in attention for short rotation coppice. Digestion and combustion receive even more attention in demonstration projects. With respect to liquid fuels attention shifts to ethanol production by fermentation of agricultural crops: it is considered the most suited biofuel when agricultural lands are available and receives strong support by sugar beet farmers and sugar industries – that try to deal with a depressed sugar world market in the early 80s [42,43,47,48,50,51,53].

Over **1989–1993**, government expenditures on energy from biomass RD&D are at a low point [54] – according to Grassi [55] budgets in the European biomass program over 1989–1991 drop by 40%. This is reflected in a limited number of conference contributions and visitors. In 1991 for the first time researchers and experts of Eastern Europe participate at the conference [56,64]. The Gulf crisis is a reminder of the dependency of oil – but the impact on oil prices and energy policies remains limited [56].

The European network has achieved a high level of scientific competence, for example in enzyme hydrolysis of cellulose and short rotation coppicing. The industrial applications of these breakthroughs are yet to emerge, with limited interest from the energy market due to the low oil prices [58]. Apart from energy production from waste, development of biomass technologies is only justifiable if external costs are internalized. Emphasis is given to lignocellulosic biomass (wood, agricultural residues like straw, etc.) [59–62].

A major driver becomes the concern about environmental problems: limiting emissions, effects of intensive land use, dealing with (the volume of) waste, and the upcoming concern on global warming [36,55,56,58,59,61,62,64–67,69,131]. The Earth Summit of Rio gives impetus that sustainability will be of growing concern and results in EU commitments to stabilize CO_2 emissions [60,69]. Another driver is rural redevelopment and support of the agricultural sector – including job opportunities. At that time it is expected that a further increase in competition from Eastern Europe and possibly from developing countries (due to the unavoidable reforms in agricultural policy) will result in more arable land set aside [55,60,62,67].

There is a start to positively reframe the contribution of renewables to the energy supply. And energy from biomass is considered *the* option to deliver at the short and medium term, being one of the most cost-effective renewables that also is widely available and widely spread. This would finally be formalized in the 1997 White Paper on renewable energy, with a leading role for biomass. As such it is quoted and defended till well after 2000. Main focus is still on biomass as an indigenous resource, which requires large integrated pilot projects on a regional scale [10,11,36,55,59–61,65,67,70–74].

In the late 80s and early 90s emphasis is given to pyrolysis: its developments seem promising, with Europe leading world developments and the liquid produced has a strategic value: it has a high energy density; it is easy to transport; it is easy to apply in heating and power applications; and it can possibly be applied as fuel blend or for the production of high value chemicals [55,62,65,75–77] In the 90s a new sector has come into focus, electricity production, with possible contributions coming from advanced technologies like fast pyrolysis and gasification using combined cycle generators. The power production sector has found itself under pressure, as after the Chernobyl accident there is little support for expanding nuclear power, and concerns regarding global warming limit the support for coal based power generation [55,56,59,60,62,67].

Energy from biomass gets wider acceptance [56]. As Grassi [55] formulated it: "*We are also witnessing greater agreement on the significance of this sector and the valuable contributions that it can make*". However, the period is one of transition and reassessing the role of energy from biomass, as reflected in the number of positioning papers, and the process shows ambivalence toward energy from biomass [75,78,79]. As de Sampaio Nunes [80] phrases it '*Energy from biomass does not enjoy the same administrative and political support as other traditional forms of energy do*'.

In the period **1994–1996** there is growing commitment to reduce greenhouse gas emissions. There is a growth in research, which shows in the budgets and number of contributions and visitors to the conference. The latter also increases due to broadening with more active participation from agricultural interest groups, government agencies and technical journals [36,54]. These come from increasingly more countries, with the EU expanding and with a growing international attention for energy from biomass [82]. Parallel to the 1996 conference also the first technology exhibition was held.

From this period on growing emphasis is given to bringing bioenergy to the market place, with more attention for commercial or near commercial demonstration activities, economy, environment, non-technical barriers and political means for accelerating the use of energy from biomass [70,74,82–85]. Where the early 80s focused on liquid fuel production, the 90s are all about power production, both large scale (combustion and IGCC) as well as small scale combined heat and power. In 2001 this becomes formalized by a directive on electricity from renewable energy sources. There is an increasing involvement of large power producers. Lignocellulosic biomass remains on top–with woody biomass already being applied at a large scale. The focus remains strongly on rural development [61,82,86,87].

In **1998–2002** these trends are followed, with an increasing attention for climate change and the upcoming of biomass combustion and co-combustion and co-firing, the latter two involving both coal and biomass as feedstock. By that time, many countries have set ambitious targets for energy from biomass. However, there is growing concern that these targets will probably only be met in exceptional cases at best – or might be achieved later on or with a shift to other renewables. If the targets are to be achieved on the short term, more efforts are necessary to remove the (mainly non-technical) barriers for implementation [74,83,88]. As the liberalization of the electricity markets progress, as a result of the EU policy on internal energy market that already started in the 1990s, the enthusiasm by power companies is tempered. Private power companies tend to have low RD&D budgets and be risk aversive – that is, if they invest at all they tend to go for proven technologies [89]. The foreseen expansion of the EU results in studies on the possible contributions or Poland and Ukraine, both large countries. In gasification, solving the persistent problems with tar becomes a focal point.

In the most recent period, **2004–2011**, oil prices rise again, mainly from 2004 on with an all time peak in 2008 [90,91]. Although this was the result of multiple causes, some influencing factors are the increased use, especially by the upcoming economies like China, and a failure at the production side to keep up with demand. As these are considered structural changes, it is expected that on average oil prices will rise and become more volatile in the future [92]. However, this has not resulted in the strong sense of urgency that characterized the response to high oil prices in the late 70s and early 80s.

More dramatically is the shift with respect to power application, where biomass has been surpassed by wind power, which became the new renewable energy technology of choice and the promise for the future. Biomass still holds a strong promise – that now focuses on application for heat, biofuels and in industrial applications [29,93–95].

Over this period especially the international dimension comes up. Trade in biofuels takes off, both in pellets (solid biomass), but also in liquid fuels that start to dominate the agenda. In Europe the driver is set in the 2003 directive on liquid biofuels with specific targets for 2005 and 2010. Interest covers both first generation biofuels as well as the development and demonstration in second generation biofuels – although application remains restricted to first generation fuels (ethanol by fermentation and biodiesel) [29,88,93,96–98,105]. The trade in biofuels relates mainly to countries like Canada, Brazil, Malaysia and Indonesia. But the scene is growing, with China and Russia also showing interest [100,103,104]. This results in new attention on strategies, policies, logistics and sustainability criteria, and interest in intermediate products (wood chips, pellets, pyrolysis oil) [105,106]. There is a growing interest in biorefineries and polygeneration. Bio-refineries may become the basis for cooperation amongst the various biomass sectors, to develop their synergies. There is also renewed attention for heat applications, the 'Cinderella' of bio-energy applications, and advanced applications like synthetic natural gas (SNG) and fuel cell applications [92,98,107–110].

There seems to be a two path strategy to implement the utilization of biomass: the first one is integration in the existing infrastructure (power, blending biofuels, synthetic natural gas for existing gas networks); while the other one focuses on implementation at the best place on earth, including Clean Development Mechanisms and Joint Implementation and biomass trade [98]. There is some renewed sensing that biomass technologies are mature and that the interest for biomass commercial implementation has increased significantly, which could possibly result in the initiation of the biomass deployment. However, there still is a need for strong policy, huge investments and strong support of other industries, especially the oil and car industries and the utilities [92,107,110,111].

Not included in this overview, but omnipresent over the years is the intensive and broad attention for biomass growing/productivity/harvesting. Also present from the start, although on a more limited scale, is the recognition of the importance of (traditional) biomass use for energy in developing countries and the possibilities that come along with it. This is very well articulated in the early 80s and remains present over the years.

Table 1
Over and under used words in different time periods, as present in titles of the European biomass conference.

Period	80–85	87–91	92–98	00–05	07–10
Over-used words					
Regions	UK, France, Sweden	France, EC, Brazil	Finland, Denmark, Austria, Portugal, EC	Europe, Greece, Sweden, Denmark, Poland, Germany, Ukraine, United States	EU, Italy, UK, Thailand, Africa
Feedstock/crop	Alga, waste, forestry, fuel wood, wood, willow, crop, straw, sugar	Coppice, tree, pulp, timbre, eucalyptus, poplar, rice husk, agro forest, Sweet Sorghum, Jerusalem artichoke, straw, cotton, refuse, charcoal, fungus	Short rotation coppice, salix, eucalyptus, Miscanthus, coal, fuel wood, forestry, chip, bark, pulp, paper, Sweet Sorghum, reed, agricultural, bagasse, MSW	Biomass, coal, fossil, fuel, Kenaf, corn, stover, Switchgrass, prune, sunflower, olive	SRF, SRC, pellet, Jatropha curcas, palm, fruit, sewage, tire
Conversion	Digestion, fermentation	Digestion, fermentation, liquefaction, hydrolysis, pyrolysis, refinery	IGCC, combustion, stirling, co-fermentation, co-digestion, combined heat and power	CHP, cogeneration, gasification, co-firing, co-combustion, Rankine	Gasification, torrefaction, bio-refinery, co-firing, ORC, extrusion
Application	Alcohol, methanol, ethanol, gasoline, gas, methane, engine	Alcohol, ethanol, methane	Electricity, heat, RME, compost	Bioenergy, gas	Biofuels, bioenergy, SNG, biogas, bio-hydrogen, syngas, SOFC, biodiesel, bioethanol
Others	Animal, farm	LEBEN, fast growing, yeast, fluidization	Plantation, non-food, ecological, carbon dioxide	CFB, tar, olivine, small scale, transportation, demonstration, socio-economic, optimization, prospect, implementation, Kyoto, NOx, life cycle, building, supercritical, CFD	GHG, CDM, mitigate, impact, sustainable, LCA, emission, chain, supply, trade, logistic, transport, pre-treatment, market, consumer, policy
Under-used words					
Regions			EU	EU, France	Denmark, Brazil, Austria
Feedstock/crop	Sorghum	Miscanthus, pellet	Switchgrass, sunflower	Sweet Sorghum, alga, Miscanthus, artichoke, fuel wood, forest, Jatropha curcas, rape, bagasse, Eucalyptus, charcoal	Waste, Sweet Sorghum, wood, coppice, Miscanthus, forestry, agriculture, eucalyptus, husk, straw, charcoal
Conversion	Combustion	Combustion, gasification	Gasifier, digestion	Fermentation, flash pyrolysis	(co)-Fermentation, digestion, hydrolysis, liquefaction
Application	Biofuels, bioenergy, power, oil	Biofuels, bioenergy, gas, power, heat, biodiesel, bioethanol	Biofuels, bioenergy, syngas, hydrogen, methane, methanol, biodiesel, bioethanol	Alcohol, ethanol, methane, biogas	Alcohol, electricity
Others	tar	Emission, ash, tar, potential market, policy, strategy	Sustainable, trade, chain, tar	Sustainable, harvest, supply, grid	Animal, pulp

5. Quantitative analysis discourse

Using T-lab software a table was created of over- and under-used words in conference contributions over different periods, see Table 1. To keep the results well-ordered, they are classified in the categories ‘regions’, ‘feedstock’, ‘conversion’, ‘application’ and ‘others. The results have been contextualized and will be discussed in thematic order, following the rows in Table 1.

Countries are selectively represented, focusing on most contributing countries. The early 80s were dominated by the contributions of the UK and France. In the 90s a series of smaller countries came up: Finland, Denmark, Austria and Portugal. For the period after 2000 the appearance of both Poland and Ukraine is striking. Both countries have been considered for their potential of biomass production, by both agriculture and forestry. Striking is also the limited reference to Germany in this period – a country known for its leading position in the field in recent years.

The contribution of feedstock can only be interpreted when being aware of its subsequent possibilities of conversion and application. In the early 80s there is mainly attention for forestry and wood, the traditional biomass sources for energy. Algae are considered as long term response to an increase of the pressure over land use. In the late 80s attention shifts and start to include short rotation coppice, including eucalyptus and poplar, and crops suited for fermentation to produce ethanol, including Sweet Sorghum and Jerusalem Artichokes. The 90s show a further increase in emphasis on short rotation coppice. Just after 2000 there is a remarkable attention for fossil fuels and especially coal, which are used in all sorts of hybrid processes using both coal and biomass. The most recent period shows extra attention for pellets, which are furthest in becoming a biomass commodity with international trade, as well as some specific waste streams like tires and sewage sludge.

The 80s start off with mainly attention for digestion and fermentation that produce, respectively, methane and ethanol, although also methanol production by gasification was considered.

As already mentioned, in the late 80s there is a shift toward fermentation and ethanol production. In the 90s there is a complete shift in focus. Fermentation and digestion and their respective products become under represented, although co-fermentation and co-digestion do receive some attention. The new kinds on the block are the use in gas turbines (IGCC) after gasification, combustion and combined heat and power – all to deliver mainly power but also heat. As such both the large and the small systems receive significant attention. After 2000 emphasis is on cogeneration (combined heat and power) and on co-firing/co-combustion, involving coal. After 2007 attention seems to broaden a bit. Gasification and co-firing are still in the spotlight, but now also bio-refineries are considered – which might actually accommodate a gasifier. There is a lot of attention for biodiesel and bioethanol. But also other, more advanced applications are considered, mainly based on gasification, for example synthetic natural gas (SNG) and fuel cells (SOFC). There is also attention for bio-hydrogen, both in general and more specific on production via a fermentation route.

In the category other lemmas we find the word animal and farm in the early 80s, that link to the emphasis on digestion and fermentation. Subsequently we see lemmas related to short rotation coppice (fast growing, LEBEN – Large European Biomass Energy Network, plantation, non-food). From the 90s onwards one can see the increase in attention for reduction of greenhouse gasses (carbon dioxide, Kyoto, greenhouse gasses GHG, clean development mechanism CDM, mitigate). Typical is the emphasis on gasification, including CFB technology and the tar problem, for the period 2000–2005. After being present since the 90s, sustainability finally breaks through in recent years. Along with that there is more attention of life cycle analysis, emissions and chain impacts. These are also the years of market formation, as reflected in lemmas like chain, supply, trade, logistics, transport, market and consumer. This involves biomass and bioenergy in general and more specific biofuels and pellets.

Table 2
Summary developments in energy from biomass RD&D and policy in Western Europe.

1980–1985	Oil crisis shock, fuels for oil replacement like methanol by gasification Coming of age, growing interest Small impact near future, strategic importance long term Large government sponsored programs, need for long term support Short term waste, medium term energy crops Importance for Third World countries Biological routes
1985–1987	Low energy prices Dealing with waste, opportunity fuel Agricultural surpluses → ethanol and short rotation forestry schemes Feedstock research and reduction of production costs
1989–1992	Idem Initially reduced interest, followed by positively reframing potential biomass Growing importance environmental problems, especially global warming International cooperation on biomass
1994–1996	Thermochemical conversion is maturing (combustion, pyrolysis, gasification) – and receives most interest Electricity (incl. large power producers) and decentralized heat and power Unemployment disadavantaged regions Setting aside of farm land to limit excess agricultural production Bringing biomass energy to the market place, advantages and barriers
1998–2002	Worldwide strategies Bringing biomass energy to the market place, policy, climate protection (Advanced) combustion Coal (co-combustion, co-gasification)
2004–2011	International cooperation Biofuels trade, logistics, sustainability debate Bio-refineries, SNG and fuel cells

6. Discussion and conclusions

6.1. Story lines

We performed a discourse analysis by two different methods, resulting in the two storylines presented above. Both show similar trends – see Table 2. The applied methods go well together: the literature based approach allows for more details and contextualization (arguments, drivers, etc.), while the quantitative approach shows that it is not just a discussion, an analysis of linguistics, but it also relates to a community effort that is represented–a discourse of language and practice.

Results also show the relevance of the supranational approach: clearly there is a shared agenda, vision and effort. The broad, long term and international focus allows identifying shift in topics, technologies and contributing countries – shifts that in studies that focus on a specific technology or country would not show up. For example, the shift in the 1990s was not just favoring gasification based IGCC – that received most of the attention –, as it turns out to be part of a much broader shift away from biochemical toward thermochemical conversion routes. When checking the contributions of the conference, by words in titles, contributions per session theme and scores in key words indices, it shows that this shift from biochemical to thermochemical conversion has been rather strong. It resulted in the fourth framework Joule-Thermie program (1994–1998).

This shift from biochemical to thermochemical routes at the end of the 80s/early 90s coincides with a shift in contributing countries, away from the major contributions by France and the UK toward Germany, Italy and a series of smaller countries, including Finland and Sweden. Although Finland and Sweden had been active in this field already in the 1980s, these developments remained largely out of sight of the European biomass conference. To some extend the developments seem to be correlated. Bridgwater [112] confirms that Europe in general, and especially France and the UK – together with Italy – took the lead in biochemical conversion in the late 1980s. However, Bridgwater also shows that the UK and France were very active in the field of thermochemical conversion of biomass. So apparently, other causes need to be considered as well. The case of the UK is not that clear, but for France we did find additional information.

In the early 1980s the energy situation in France was characterized by high dependency on oil import and a high potential of biomass [113,114]. Small scale air gasifiers found initial application, while France also actively participated in the EU gasification-to-methanol research [115,116]. However, methanol production by this route could not compete with the low oil prices – that become a fact of life in the mid 80s. In the EU in the 1990s, research was refocused to gasification for power generation (see the storyline [70]). However, for France this was not an attractive route to pursue, as it already shifted to nuclear power production in the 1980s on a large scale. Public funding of research on biomass gasification for power production was stopped in 1987 and France buy-back tariffs for power showed to be one of the worst in Europe [1,117,118]. With the renewed interest in biofuels after 2000, France mainly focused on first generation fuels.

6.2. Duality

The discourse on energy from biomass is surrounded by duality. For example, energy from biomass can be both culprit and savior

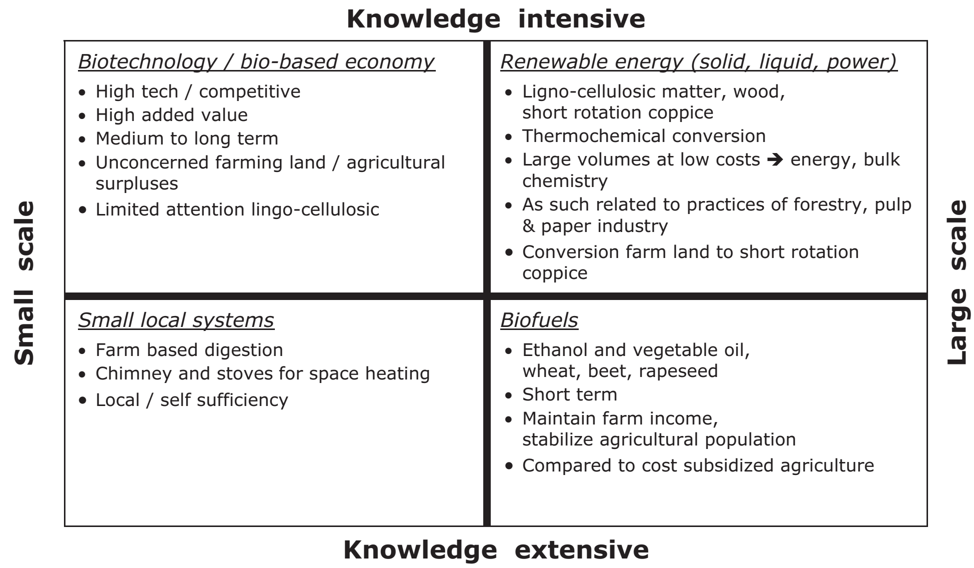


Fig. 2. Four discourses in energy from biomass.

for sustainable energy production. Surprisingly, already early on both the possible competition on land for food production and the energy balances received interest, as well as the impact of intensive land use (see, e.g. Hall [9]). In the 90s attention intensified and focused on environmental problems and sustainability issues, including the discussion on sustainability criteria. Nevertheless, the biofuels directive of 2003 resulted in some mall practices and the public food versus fuel debate after the 2007–2008 world food prices crisis [119]. This debate evolved around similar arguments that were already used by Hall in 1982 [9]. This raises the question how these arguments failed to make a contribution to the biofuel directive.

Lehrer [17, p. 440] describes a similar situation with respect to the US legislation over 2007–2008 with regard to biofuel development. "*While concerns were raised about the environmental impacts of large-scale government investment in biofuels, these concerns gained political traction only after the 2007 (energy) and 2008 (farm bill) laws were passed*". She concludes that "*policy is created at a particular moment in time and is influenced by situational, political and discursive forces that shape the type of policy change that becomes possible at that time*". She argues that discourse analysis can play an important role in identifying (and understanding) the opening and closing of these policy windows – the windows of opportunity for policy development in the given context.

Another omnipresent duality is that of time horizons. On the one hand there is the focus on energy from biomass as a strategic option. This includes decreasing the dependency on oil and application to reduce greenhouse gasses. This focus also relates to innovation: new, efficient and cheap technology that is a promise for the future; and highly productive crops and growing methods. As such it allows for long term RD&D trajectories that could easily encompass one or more decades.

On the other hand there is a continuous pressure for short term application: to reduce the actual dependency on oil, to start reducing greenhouse gasses, to support rural areas and farmers, and to involve market parties and their sources and dynamics. The storylines clearly show the tension between the two approaches – long versus short term – that frequently require different policies, but also lead to different choices with respect to feedstock and technologies.

6.3. Discourses and discursive shifts

Energy from biomass continues to be used as key word in potential studies, renewables and energy policy. However, as the story lines show, this is a non-homogeneous and ambiguous concept, a label that to some extent disguises the broad and complex options that it represents. It includes a wide variety of feedstock (wood, agricultural crops and residues, waste, algae), conversion processes (digestion, fermentation, combustion, pyrolysis, gasification, liquefaction, etc.) and applications (heat, power, fuels, chemicals, large vs. small scale), while also the drivers to work on these options change over time. Overall, one can say that energy from biomass referred to something completely different in the early 80s, compared to the mid 90s or to 2010. And it is this change in discourse that we are interested in.

This variety in options provides on the one hand what innovation scientists call *interpretive flexibility* – no matter what the new policy goal or large societal problems or promises are, energy from biomass can adapt to that like a chameleon and continues to receive some support. On the other hand, learning effects between options will be limited, each option will involve its own actors, and building up an image to the general public and media remains difficult, while other renewables like solar and wind seem to provide a much clearer profile. This is further eroded by the quarrels between different biomass conversion options [83,87,108,120].

Several authors have structured these developments in one way or another. We will follow Chartier [58] who distinguishes strategies based on knowledge intensity and scale, see Fig. 2. Each of the strategies also comes with different feedstock, conversion technologies and applications, and as such with different actors and supportive arguments. As these strategies fit well with our story lines, we will argue that they constitute different discourses that together have shaped the path of developments and as such can be used to analyze them.

The first one relates to biofuels (bottom right) and is focused on large scale ethanol and biodiesel production to use agricultural surpluses and support rural development. Research plays a secondary role in this strategy, as these were already more or less established technologies in the 1980s.

The second strategy relates to renewable energy (top right) and is focused on the large scale production of solid and liquid fuels

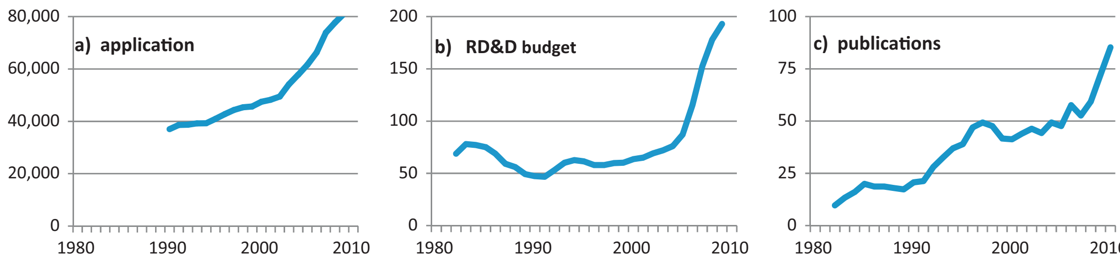


Fig. 3. Trends in energy from biomass in EU-15: (a) in application (thousand tons of oil equivalents) (source: [93]); (b) total of national RD&D budgets on energy from biomass (million euro, 2009 prices and exchange rates; 3 year moving average) (source: [54]); and (c) number of publications, in this case in Biomass (1982–1990) and in Biomass & Bioenergy (1991–2010; 3 year moving average) [20].

and power, with an active interest in lingo-cellulosic matter. This includes options like advanced combustion, pyrolysis and gasification. This requires significant research and focuses on power and fuel production.

The third strategy (top left) is focused on knowledge intensive biotechnology, with high added value products produced in small quantities. Examples include applications like fiber, specialty chemicals, biopolymers, lubricants, paints, etc. More importantly, this third strategy relates to what became known as the bio-based economy, a vision that received increasingly attention after 2000. Although in principal this refers to the more broad development away from fossil fuels to bio-materials as feedstock for energy and materials, its more specific promise is building strongly upon biotechnology – see also [19,121,122].

We added a fourth strategy (bottom left) – one that was not mentioned by Chartier – that relates to small scale and knowledge extensive application. This includes farm based digestion system and traditional combustion of biomass.

Clearly, developments can be described as shift in attention between the four discourses. This is especially relevant as each involves a different policy arena and different actors.

European efforts in the early 80s mainly focused on developing and applying *small local systems*, including digesters; and on research and development on *renewable energy* that focused on methanol production by wood gasification for blending in petrol. Both technology and feedstock were considered suited (on the long run) for large scale application. Main driver is finding domestic sources that can substitute oil. In the late 80s the context shifts, as the oil prices no longer provide an incentive and the agricultural overproduction increasingly becomes a problem. Ethanol as *biofuel* is reconsidered. In the 90s attention shifts away from biochemical routes to thermochemical applications and the *renewable energy strategy*. After 2000 attention diverges again. There is continued interest in *renewable energy:* gasification in research and development and (co-) combustion in applications. At the same time the *biofuel* market opens up, while there is also an increase in attention for the vision of a *bio-based economy*.

Note that small local applications have to some extent been part of these developments, like the emphasis on digestion systems in the 1980s. However, it never received high priority since, although several sources indicate that small system, especially combustion for space heating, continue to make a significant contribution [28,95].

Also note that, although Chartier already in 1990 points at the increasing importance of agro-food industry focusing on new high-added value products, the promise of a bio-based economy is mainly articulated by other and more recent literature and received limited attention on the conference. Apparently the conference is not the best platform for life sciences, biochemistry, biotechnology, genetics, etc.

Some of the developments cannot be fully captured by the identified discourses. Examples are the recent interest in bio-refineries that can be seen as an attempt to bridge the biotechnology and the renewable energy approach; or the fermentation of lignocellulosic biomass, which is a cross over between the biofuel route and the renewable energy route.

Of course, one can also focus on the developments within each of these discourses. For example ethanol production that in the early 1980s was mainly considered for small applications with significant attention for the fermentation process. During the late 80s and 90s its role as potential biofuel is strengthened. When this materializes after 2000, the discussion is no longer about the fermentation process and technology, but about biofuels in their socio-economical context: policy, barriers, economics, trade, logistics, sustainability criteria, etc.

7. Future of energy from biomass

Our results show for energy from biomass the 1980s as an area or exploration; the 1990s initial application for power production and glorious expectations of the future; and after 2000 the market on biofuels that opens up but also leads to a public debate and wind that takes over the power market. Where does it leave us? Has energy from biomass outlived its days of success of the 1990s? And what does this mean for the four discourses identified? Will they blend together, or will one become dominant, or will they continue to co-exist?

In Fig. 3 some additional indicators are presented for the EU-15 (Western Europe), namely the total application of biomass for energy purposes, the total government based RD&D budgets and trends in scientific publications. Each to some extent shows the increased attention during the 1990s. But what stands out is the sharp increase after 2005. Apparently, the opening up of the combustion and the biofuel market and the start up of the international market has brought new dynamics to the field.

According to Beurskens and Hekkenberg [29] – based on projections of the EU member states – the increase in application over the next decade will mainly take place in conservative applications, like heating, power production and first generation biofuels. However, the promise of a bio-based economy recently received increasing attention. At the same time, the long term promises that have driven the field over the past decades persist in relevance: that of reduced dependency on oil and reducing greenhouse gasses – both of which will require a large scale and advanced applications. In short: all signs show that the upcoming 30 years will be at least as interesting – as well as diversified! As a result, the multiple discourses identified are likely to continue to co-exist.

References

[1] Kaltschmitt M, Rösch C, Dinkelbach L. Biomass gasification in Europe. Luxembourg: Office for official publications of the European Communities;1998.
[2] Kwant KW, Knoef H. Status of gasification in countries participating in the IEA and GasNet activity; 2004.

[3] Faaij AP. Bio-energy in Europe: changing technology choices. Energy Policy 2006:322–42.
[4] Bio-energy Council. Bioenergy 80: world congress and exposition. Washington: Bio-energy Council; 1980.
[5] Klass D. Energy from biomass and wastes: a review and 1983 update. Resources and Conservation 1985:157–239.
[6] Klass D. Energy from biomass and wastes: 1985 update and review. Resources and Conservation 1987:7–84.
[7] Office of the Biomass Programme. Biomass. Multi year programme plan. U.S. Department of Energy; 2009.
[8] Wu C, Yin X, Yuan Z, Zhou Z, Zhuang X. The development of bioenergy technology in China. Energy 2010:4445–50.
[9] Hall D. Editorial, biomass for energy in Europe. Biomass 1982:239–44.
[10] Hall D, House J. Biomass energy in Western Europe in 2050. Land Use policy 1995:37–48.
[11] Hall D. Biomass energy in industrialised countries – a view of the future. Forest Ecology and Management 1997:17–45.
[12] Hall S. Foucault: power, knowledge and discourse. In: Wetherell M, Taylor S, Yates S, editors. Discourse theory and practise. London: Sage Publications; 2001. p. 72–81.
[13] Hajer M, Versteeg W. A decade of discourse analysis of environmental politics: achievements, challenges, perspectives. Journal of Environmental Policy & Planning 2005:175–84.
[14] Fairclough N. Analysing discourse, textual analysis for social research. Routledge: Oxon; 2003.
[15] Zschach U, von Cramon-Taubadel S, Theuvsen L. Public interpretations in the discourse of bioenergy – a qualitative media analyis. Berichte Uber Landwirtschaft 2010:502–12.
[16] Sengers F, Raven R, Venrooij Av. From riches to rags: biofuels, media discourses and resistance to sustainable energy technologies. Energy Policy 2010:5013–27.
[17] Lehrer N. (Bio)fueling farm policy: the biofuels boom and the 2008 farm bill. Agriculture and Human Values 2010:427–44.
[18] Huttunen S. Ecological modernisation and discourses on rural non-wood bioenergy production in Finland from 1980 to 2005. Journal of Rural Studies 2009:239–47.
[19] Asveld L, Est R, Stemerding vD. Getting to the core of the bio-economy: a perspective on the sustainable promise of biomass. The Hague: Rathenau Instituut; 2011.
[20] Thomsom Reuters. ISI web of knowledge-web of science; 2011.
[21] Lancia F. T-lab software, tools for text analysis; 2010.
[22] Lancia F. User's manual T-lab – tools for text analysis. Opgehaald van T lab; September 2010. http://www.tlab.it/en/presentation.php.
[23] Neuendorf K. Content analysis – a contrast and complement to discourse analysis. Qualitative Methods Newsletter 2004;(Spring):33–6.
[24] Hardy C, Harley B, Philips N. Discourse analysis and content analysis: two solitudes? Qualitative Methods Newsletter 2004;(Spring):19–22.
[25] FAO. Global forest resources assessment 2005. Rome: FAO; 2006.
[26] Paappanen T, Leinonen A, Hillebrand K. Fuel peat industry in EU, summary report. VTT; 2006.
[27] Eurostat. Eurostat – agricultural products. In: Agricultural statistics, main results 2007–2008. Luxembourg: Office for Official Publications of the European Communities; 2009.
[28] EurObserv'ER. Solid biomass barometer. Primary energy production of solid biomass in the European Union in 2006. Systèmse Solaires, le journal des énergies renouvelables 2008;(December (188)):69–84.
[29] Beurskens L, Hekkenberg M. Renewable energy projections as published in the national renewable energy action plans of the European member states. Petten: ECN; 2011.
[30] Palmberger B. Bioenergy 80: world congress and exhibition. Washington: Bioenergy Council; 1980. p. 343.
[31] Asplund D, Sahrman K, Solantausta Y. The energy from wood and research on wood energy in Finland. In: Council B-e, editor. Bioenergy 80: world congress and exposition. Washington: Bio-energy Council; 1980. p. 311–4.
[32] Kurkela E. Status of peat and biomass gasification in Finland. Biomass 1989:287–92.
[33] Sipilä K, Kurkela E, Solantausta Y. New options for biomass-based power production by IGC. A Finnish national research programme – JALO. In: Bridgwater A, editor. Advances in thermochemical biomass conversion 1992. Glasgow: Blackie Academic & Professional; 1993/1994. p. 77–86.
[34] Pettersson E. Bio-energy in Sweden. In: Bioenergy 80: world congress and exposition. Washington: Bio-energy Council; 1980. p. 20–2.
[35] Ström E, Liinanki L, Sjöström K. Gasification of biomass in the MINO-process. In: Egneus H, Ellegard A, editors. Bioenergy, vol. 84. London: Elsevier Applied Science Publishers Ltd.; 1985. p. 57–64.
[36] Scheer H. Towards a strategy for development and propagation of bio-energy in the single European market. In: 8th European biomass conference. 1995. p. 5–10.
[37] Chartier P, Palz W. The second European Community programme on energy from biomass. In: Bio-energy '80: world congress and exposition. Washington: Bio-Energy Council; 1980. p. 321–5.
[38] Chartier P, Hall D. Summary report of the co-chairmen of the conference. In: 1st European biomass conference. 1981. p. 2–6.
[39] Clarke F, Strub A, Ghose T, Berger B. Foreword. In: 1st European biomass conference. 1981. p. v–vi.
[40] Williams L. Opening speech. In: 1st European biomass conference. 1981. p. 14–8.
[41] Strub A, Chartier P, Schleser G (Red.) Energy from biomass, 2nd E.C. conference 1982. Brussels and Luxembourg: Commission of the European Communities/Applied Science Publishers; 1983.
[42] Chartier P. Summing up and evaluation of biomass prospects. In: 2nd European biomass conference. 1983. p. vii–ix.
[43] Strub A, Chartier P, Schleser G. Preface. In: 2nd European biomass conference. 1983. p. v.
[44] Hall D. Food versus fuel, a world problem? 2nd European biomass conference. 1983. p. 43–62.
[45] Strub A. The Commission of the European Communities R&D Programma 'Energy from Biomass'. In: Bridgwater A, editor. Thermochemical processing of biomass. Butterworths; 1984. p. 1–10.
[46] Strub A. The energy from biomass programme of the Commission of the European Communities. In: 3rd European biomass conference. 1985. p. 3–5.
[47] Fabry R, Goudeau J-C. Thermal conversion of biomass and waste by combustion and pyrolysis/gasification, CEC directorate-general for energy demonstration programme. In: 4th European biomass conference. 1987. p. 274–82.
[48] Fabry R, Ferrero G. Implementation and results of the commission's energy demonstration programme. In: 5th European biomass conference. 1990. p. 2.1158–64.
[49] Grassi G, Pirrwitz D. The European Community's research and development programme for energy from biomass. In: 2nd European biomass conference. 1983. p. 659–63.
[50] Hall D, Palz W. Preface. In: 3rd European biomass conference. 1985. p. v.
[51] Hall D, Coombs J. Round tables. In: 3rd European biomass conference. 1985. p. 236–9.
[52] Grassi G, Delmon B, Molle J-F, Zibetta H (Red.) Biomass for energy and industry, 4th E.C. conference 1987. Brussels and Luxembourg: Commission of the European Communities/Elsevier Applied Science; 1987.
[53] Grassi G, Delmon B, Molle J-F, Zibetta H. Preface. In: 4th European biomass conference. 1987. p. v.
[54] OECD/IEA. R&D statistics. Opgeroepen op 2011, van IEA International Energy Agency; 2011. http://www.iea.org/stats/rd.asp.
[55] Grassi G. 6th European conference on biomass. In: 6th European biomass conference. 1992. p. 27–9.
[56] Chartier P. General synthesis of the conference. In: 6th European biomass conference. 1992. p. 1406–14.
[57] Grassi G, Collina A, Zibetta H (Red.) Biomass for energy, industry and environment, 6th E.C. conference 1991. Brussels and Luxembourg: Commission of the European Communities/Elsevier Applied Science; 1992.
[58] Chartier P. Biomass fore energy and industries: fifth European conference (Lisbon) executive summary. In: 5th European biomass conference. 1990. p. 2.1169–75.
[59] Chartier P. Synopsis of sessions and prospects for biomass. In: 7th European biomass conference. 1994. p. 363–7.
[60] Allgeier H, Caratti G, Sandberg O. Towards a European BIO-ENERGY strategy. In: 8th European biomass conference. 1995. p. 11–9.
[61] Auken. Opening remarks at the 9th European bioenergy conference. In: 9th European biomass conference. 1996. p. 5–8.
[62] Grassi G. Overview of thermochemical conversion R&D activities of the CEC. In: Bridgwater A, editor. Advances in thermochemical biomass conversion, Interlaken 1992. Glasgow/London: Blakie Academic & Professional/Chapman & Hall; 1993. p. 52–62.
[63] Grassi G, Gosse G, dos Santos G (Red.) Biomass for energy and industry, 5th E.C. conference 1989. Brussels and Luxembourg: Commission of the European Communities/Elsevier Applied Science; 1990.
[64] Grassi G, Collina A, Zibetta H. Preface. In: 6th European biomass conference. 1992. p. v.
[65] Grassi G. The European R&D programme, strategy for the future. In: Bridgwater A, Kuester J, editors. Research in thermochemical biomass conversion. Essex: Elsevier Science Publishers; 1988. p. 16–30.
[66] Grassi G. Definition dún programme biomasse. In: 5th European biomass conference. 1990. p. 1.39–48.
[67] Grassi G. Strategy for biomass implementation. In: 6th European biomass conference. 1994. p. 263–71.
[68] Hall D, Grassi G, Scheer H (Red.) Biomass for energy and industry 7th E.C. conference 1992. Brussels and Luxembourg: Commission of the European Communities/Ponte Press; 1994.
[69] Hall D, Grassi G, Scheer H. Preface. In: 7th European biomass conference. 1994. p. v.
[70] Bridgwater A. The technical and economic feasibility of biomass gasification for power generation. Fuel 1995:631–53.
[71] European Commission. Energy for the future, renewable sources of energy. White paper for a Community strategy and action plan. Luxembourg: European Commission; 1997.
[72] Schmidt A. Biomass projects in Europe. In: 6th European biomass conference. 1992. p. 95–100.
[73] Maniatis K, Guiu G, Riesgo J. The European Commision perspective in biomass and waste thermochemical conversion. In: Bridgwater A, editor. Pyrolysis and gasification of biomass and waste, proceedings of an expert meeting 2002. Berks: CPL Press; 2003. p. 1–18.

[74] Beenackers A. The main conclusions from the first world conference and exhibition on biomass from energy and industry, Sevilla (2000). In: 1st World conference on biomass for energy and industry. 2001. p. lxi–v.
[75] Grassi G. Introductory remarks. In: 7th European biomass conference. 1994. p. 2.
[76] Bridgwater A, Beenackers A. Gasification and pyrolysis of biomass in Europe. In: 5th European biomass conference. 1990. p. 2.827–30.
[77] Bridgwater A. Biomass pyrolysis technologies. In: 5th European biomass conference. 1990. p. 2.489–96.
[78] Colombo U. Keynote address. In: 1st European biomass conference. 1994. p. 3–8.
[79] Bettini V. Keynote address. In: 7th European biomass conference. 1994. p. 9–12.
[80] de Sampaio Nunes P. The role of biomass in the European energy policy – keynote address. In: 8th European biomass conference. 1995. p. 20–9.
[81] Chartier P, Ferrero G, Henius U, Hultberg S, Sachau J, Wiinblad M (Red.) Biomass for energy and the environment. Proceedings of the 9th European biomass conference 1996. Oxford: Pergamon/Elsevier Science Ltd.; 1996.
[82] Chartier P, Ferrero G, Henius U, Hultberg S, Sachau J, Wiinblad M. Preface. In: 9th European biomass conference. 1996. p. v–vi.
[83] Rösch C, Kaltschmitt M. Energy from biomass – do non-technical barriers preven an increased use? Biomass and Bioenergy 1999:347–56.
[84] McCormick K, Kaberger T. Key barriers for bioenergy in Europe: economic conditions, know-how and institutional capacity, and supply chain coordination. Biomass & Bioenergy 2007:443–52.
[85] Mitchell C, Bridgwater A, Stevens D, Toft A, Watters M. Technoeconomic assesment of biomass to energy. Biomass and Bioenergy 1995:205–26.
[86] Millich E. Opening session, key note speech. In: 1st World conference on biomass for energy and industry. 2001. p. xlv–vi.
[87] Palz W. Keynote speech. Biomass, the energy of the past and the energy of the future. In: 12th European biomass conference. 2002. p. xxx–xii.
[88] Spitzer J. Amsterdam 2002 – what have we accomplished? 12th European biomass conference. 2002. p. xxxvii–ix.
[89] Burdon I. The future for advanced thermal conversion technologies – the commercial perspective. In: Bridgwater A, editor. Pyrolysis and gasification of biomass and waste, proceedings of an expert meeting 2002. Berk: CPL Press; 2003. p. 19–21.
[90] IEA. Key world energy statistics. IEA; 2010.
[91] Wikipedia contributors. Price of petroleum. Opgeroepen op May 2011, van Wikipedia, the free encyclopedia; May 18, 2011. http://en.wikipedia.org/w/index.php?title=Price_of_petroleum&oldid=429767547.
[92] Hirst N. Address from the International Energy Agency – IEA. In: 15th European biomass conference. 2007. p. lxii–ii.
[93] Eurostat European Commission. Energy. Opgeroepen op 2011, van; 2011. http://epp.eurostat.ec.europa.eu/portal/page/portal/energy/introduction.
[94] Jäger-Waldau A, Ossenbrink H. Progress of electricity from biomass, wind and photovoltaics in the European Union. Renewable and Sustainable Energy Reviews 2004:157–82.
[95] Eurostat, Roubanis N, Dahlström C, Noizette P. Renewable energy statistics. Eurostat. European Union; 2010.
[96] Hamelinck C, Bain R. Syngas for synfuels – workshop report. In: Bridgwater A, editor. Pyrolysis and gasification of biomass and waste, proceedings of an expert meeting 2002. Berks: CPL Press; 2003. p. 693–6.
[97] Fjällström T. Highlights on the technical programme. In: 2nd World conference on biomass for energy, industry and climate protection. 2004. p. xxviii.
[98] Kwant KW. Conference summary. In: 2nd World conference on biomass for energy, industry and climate protection. 2004. p. l–lii.
[99] Swaaij W, Fjällström v, Helm T, Grassi PA (Red.) Second world biomass conference. Biomass for energy, industry and climate protection. 2004. Florence: ETA Florence and WIP Munich; 2004.
[100] Grassi B, Utria B. Overview of world wide activities in international cooperation (round table). In: 2nd World conference on biomass for energy, industry and climate protection. 2004. p. 71–4.
[101] Sjunneson L, Carrasco J, Helm P, Grassi A (Red.) 14th European biomass conference. Biomass for energy, industry and climate protection 2005. ETA Florence and WIP Munich; 2005.
[102] Maniatis K, Grimm H-P, Helm P, Grassi A (Red.) 15th European biomass conference. From research to market deployment. Florence: ETA Renewable Energies and WIP Renewable Energies; 2007.
[103] Sjunneson L, Carrasco J, Helm P, Grassi A. Foreword. In: 14th European biomass conference. 2005. p. xli.
[104] Maniatis K, Grimm H-P, Helm P, Grassi A. Foreword. In: 15th European biomass conference. 2007. p. liv.
[105] Swaaij W, Prins W, Kersten S. Strategies for the future of biomass for energy, industry and climate protection. In: 2nd World conference on biomass for energy, industry and climate protection. 2004. p. xxxix–lii.
[106] Dallemand J. 17th biomass conference technical report. In: 17th European biomass conference. 2009.
[107] Carrasco J. Summary of the conference results. In: 14th European biomass conference. 2005. p. liii–vi.
[108] Pease. The policy bioenergy debate: can bioenergy deliver the required market penetration? 15th European biomass conference. 2007. p. lxxi–xix.
[109] ETA/WIP. The policy bioenergy debate. Can bioenergy deliver the required market penetration? 15th European biomass conference. 2007. p. lxxiii–xix.
[110] Maniatis K. Opening of the closing session and summary of the conference. In: 15th European biomass conference. 2007. p. lxv–vi.
[111] Palz W. Flashback to the conference and announcement of the next European biomass conference. In: 15th European biomass conference. 2007. p. lxx.
[112] Bridgwater T. Thermochemical and biochemical biomass conversion activities. Biomass and Bioenergy 1992;2(1–6):307–18.
[113] Durand H. The French bioenergy programme. Energy from biomass. In: 1st EC conference 1980. 1981. p. 826–37.
[114] Chartier P. Prospects for energy from biomass in the European Community. In: 1st European biomass conference. 1981. p. 22–33.
[115] Beenackers A, van Swaaij W. The biomass to synthesis gas pilot plant programme of the C.E.C.; a first evalution of its results. In: Energy from biomass, 3rd EC conference. 1985. p. 120–45.
[116] Bridgwater A, Beenackers A. Research priorities in thermal conversion technology. In: 3rd European biomass conference. 1985. p. 247–62.
[117] Edouard L. The relationship between coal and nuclear power for electricity production: a strategy for electricity production in France. Energy 1986:1293–7.
[118] Boissonnet G, Boudet N, Seiler J-M, Duplan J-L. Process simulation and comparison of several biomass gasification routes for the production of Fischer–Tropsch liquids. In: Biomass for energy, industry and climate protection, 14th EC conference. 2005. p. 588–91.
[119] Wikipedia contributors. Food vs. fuel. Opgeroepen op 2011, van Wikipedia, The free encyclopedia; April 28, 2011. http://en.wikipedia.org/w/index.php?title=Food_vs._fuel&oldid=426304070.
[120] Maniatis K. Message from IEA bioenergy. In: 14thEuropeanbiomassconference. 2005. p. xlix–l.
[121] OECD. The bioeconomy to 2030: designing a policy agenda. OECD; 2009.
[122] EuropaBio (2008–2011) Bio-based economy. Opgeroepen op 2011, van; 2011. http://www.bio-economy.net.
[123] Palz W, Chartier P, Hall D (Red.) Energy from biomass, 1st E.C. conference 1980. Brussels and Luxembourg: Commission of the European Communities/Applied Science Publishers; 1981.
[124] Palz W, Coombs J, Hall D (Red.) Energy from biomass, 3rd E.C. conference 1985. Brussels and Luxembourg: Commision of the European Communities/Elsevier Applied Science Publishers; 1985.
[125] Chartier P, Beenackers A, Grassi G (Red.) Biomass for energy, environment agriculture and industry. Proceedings of the 8th European biomass conference 1994. Oxford: Pergamon/Elsevier Science Ltd.; 1995.
[126] Kopetz E, Weber T, Palz W, Chartier P, Ferrero G (Red.) Biomass for energy and industry. 10th European conference and technology exhibition 1998. Rimpar: C.A.R.M.E.N.; 1998.
[127] Kyritsis S, Beenackers A, Helm P, Grassi A, Chiaramonti D (Red.) 1st World conference on biomass for energy and industry. 2000. London: James & James Ltd.; 2001.
[128] Palz W, Sptizer J, Maniatis K, Kwant K, Helm P, Grassi A (Red.) Twelfth European biomass conference. Biomass for energy, industry and climate protection 2002. Florence: ETA Florence and WIP Munich; 2002.
[129] Schmid J (Red.) 16th European biomass conference & exhibition. From research to industry and markets. Florence: ETA Florence Renewable Energies; 2008.
[130] De Santi G, Dallemand J, Ossenbrink H, Grassi A, Helm P (Red.) 17th European biomass conference. From research to industry and markets. Florence: ETA Florence Renewable Energies; 2009.
[131] Grassi G, Gosse G, dos Santos G. Preface. In: 5th European biomass conference. 1990. p. v–vii.
[132] Spitzer J (Red.) 18th European biomass conference and exhibition. From research to industry and markets. Florence: ETA Florence Renewable Energies; 2010.
[133] Turkenburg WC. Renewable energy technologies. In: UNDP world energy assessment. Energy and the challenge of sustainability. New York: UNDP; 2000. p. 266.